Idaho National Engineering and Environmental Laboratory

Modeling Space Reactors with ATHENA

Presented by

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ATHENA

Advanced Thermal-Hydraulic Energy Network Analyzer

- *Developed as an extension to the RELAP5 code (LWR nuclear reactor accident analysis)*
- *Models transient fluid flow in user-defined thermal-hydraulic networks*
- *Fifteen working fluids available*
- *Applications have included:*
  - *Tokamak fusion reactor*
  - *Cryogenic storage and delivery systems*
  - *SP-100 nuclear system*

ATHENA Modeling Features

- *Single or two-phase flow*
- *1-, 2-, or 3- dimensional flow networks*
- *Reactor kinetics – 1-, 2-, or 3-dimensional nodal kinetics model*
- *Heat Transfer – conduction, convection, radiation*
- *Components – pumps, valves, phase-separators, accumulators, jet-mixers, pressurizers, heat pipes, and turbines*
- *Process models – critical flow, abrupt area change, form loss, phase separation at tees*
- *User-defined gravitational constant*
- *Control systems*
- *Graphical user interface*

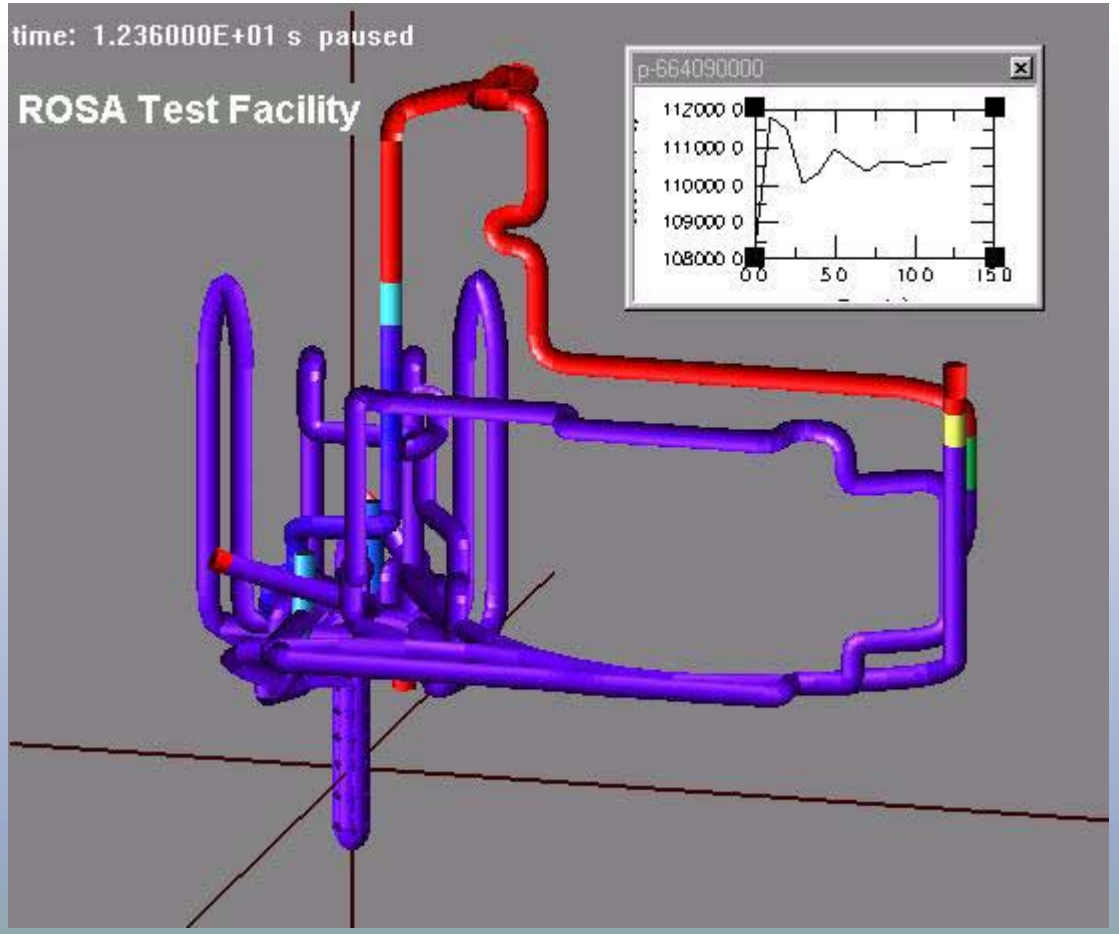
ATHENA Working Fluids

- *Light water*
- *Heavy water*
- *Hydrogen*
- *Carbon Dioxide*
- *Helium*
- *Nitrogen*
- *Lithium*
- *Potassium*
- *Sodium*
- *Glycerin*
- *Lead-Bismuth*
- *NaK*
- *Lithium-Lead*
- *Ammonia*
- *Blood*

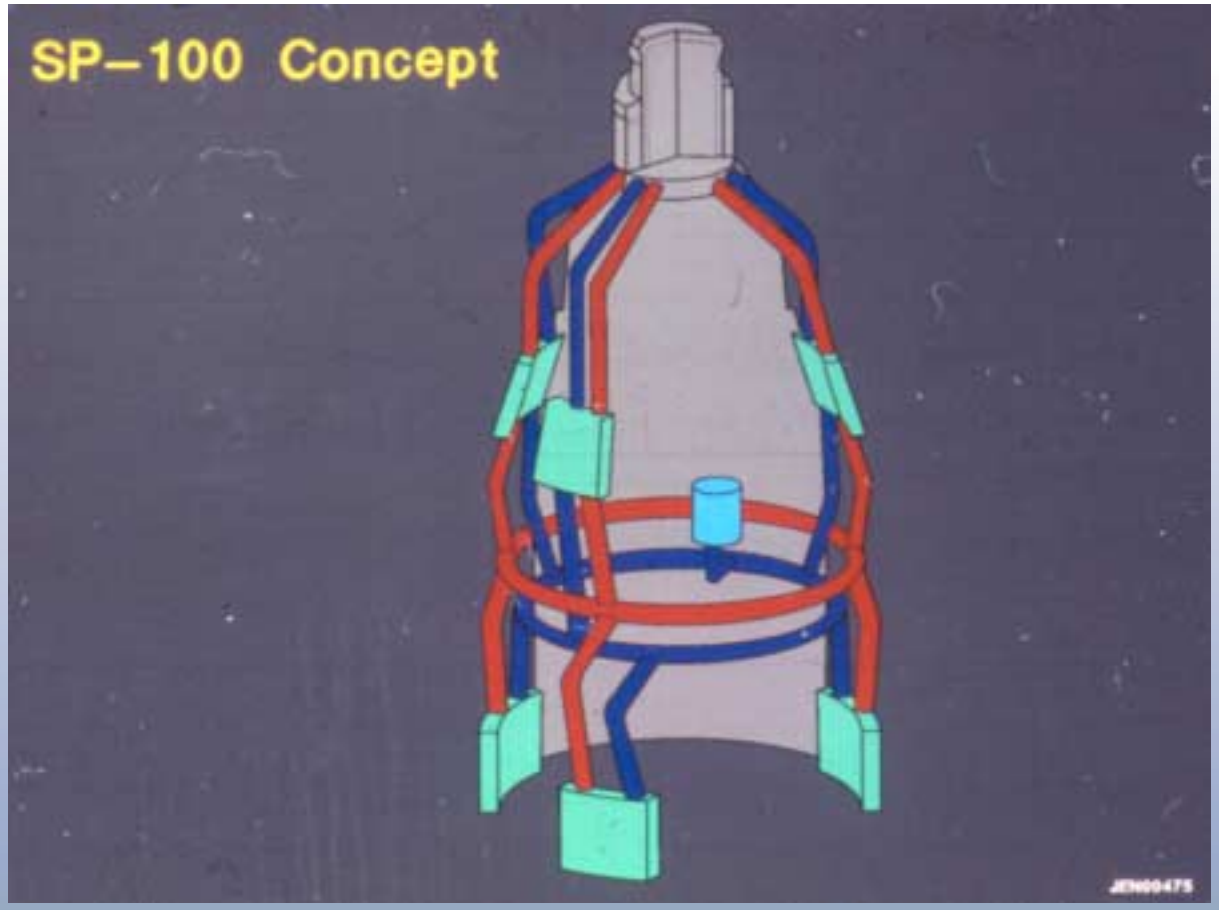
Different fluids can exist in separate loops

The graphical user interface facilitates analysis of calculated results

- Graphical display generated from input data
- Color scale displays user-selected parameter
- Point & click plots
- Replay capability at any speed

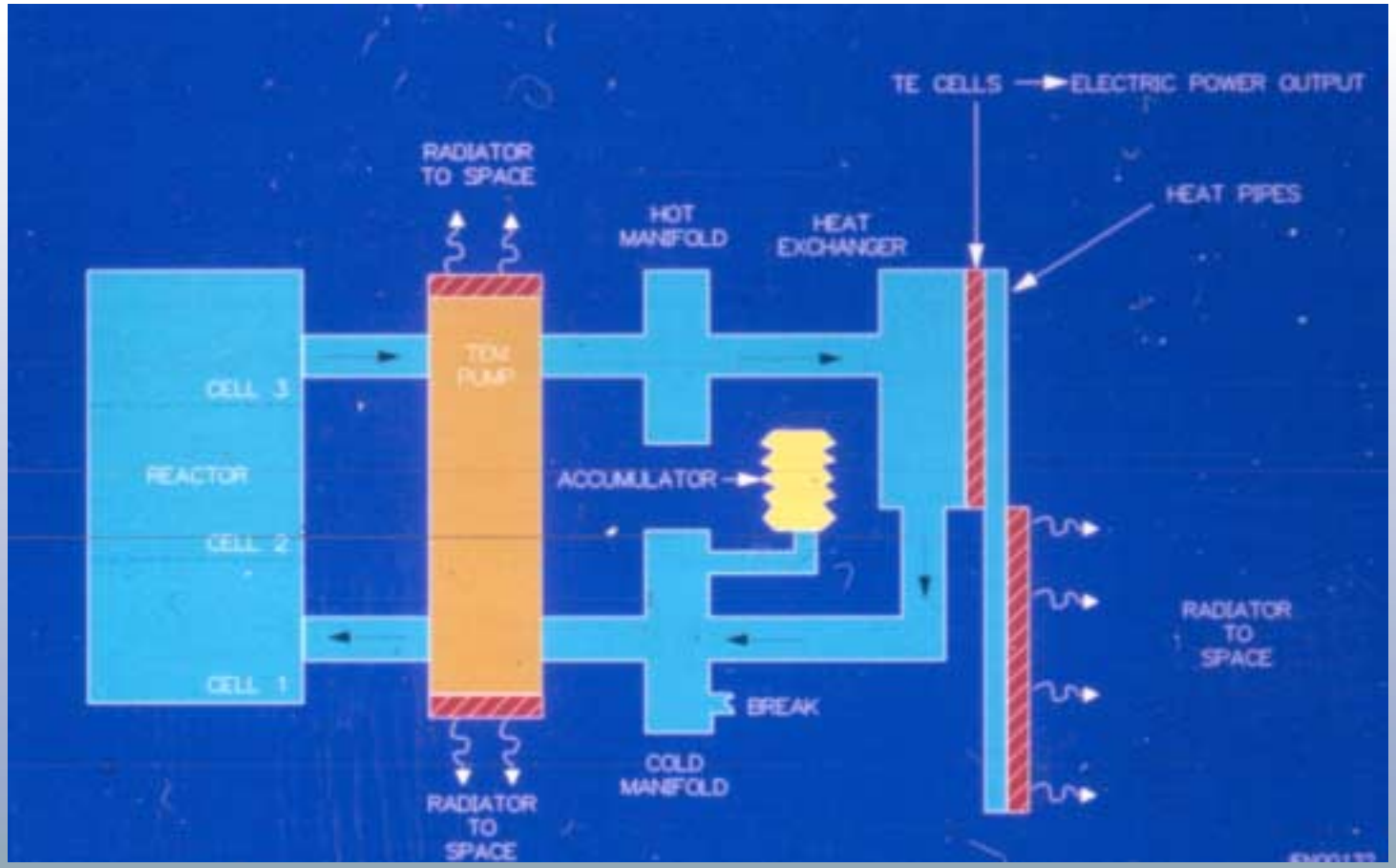


ATHENA was used to analyze SP-100*



*Roth, P.A., *Capabilities of the ATHENA Computer Code for Simulating Thermal-Hydraulic Responses Of Space Reactors, EGG-RTH-7404, September 1986.*

ATHENA model of SP-100



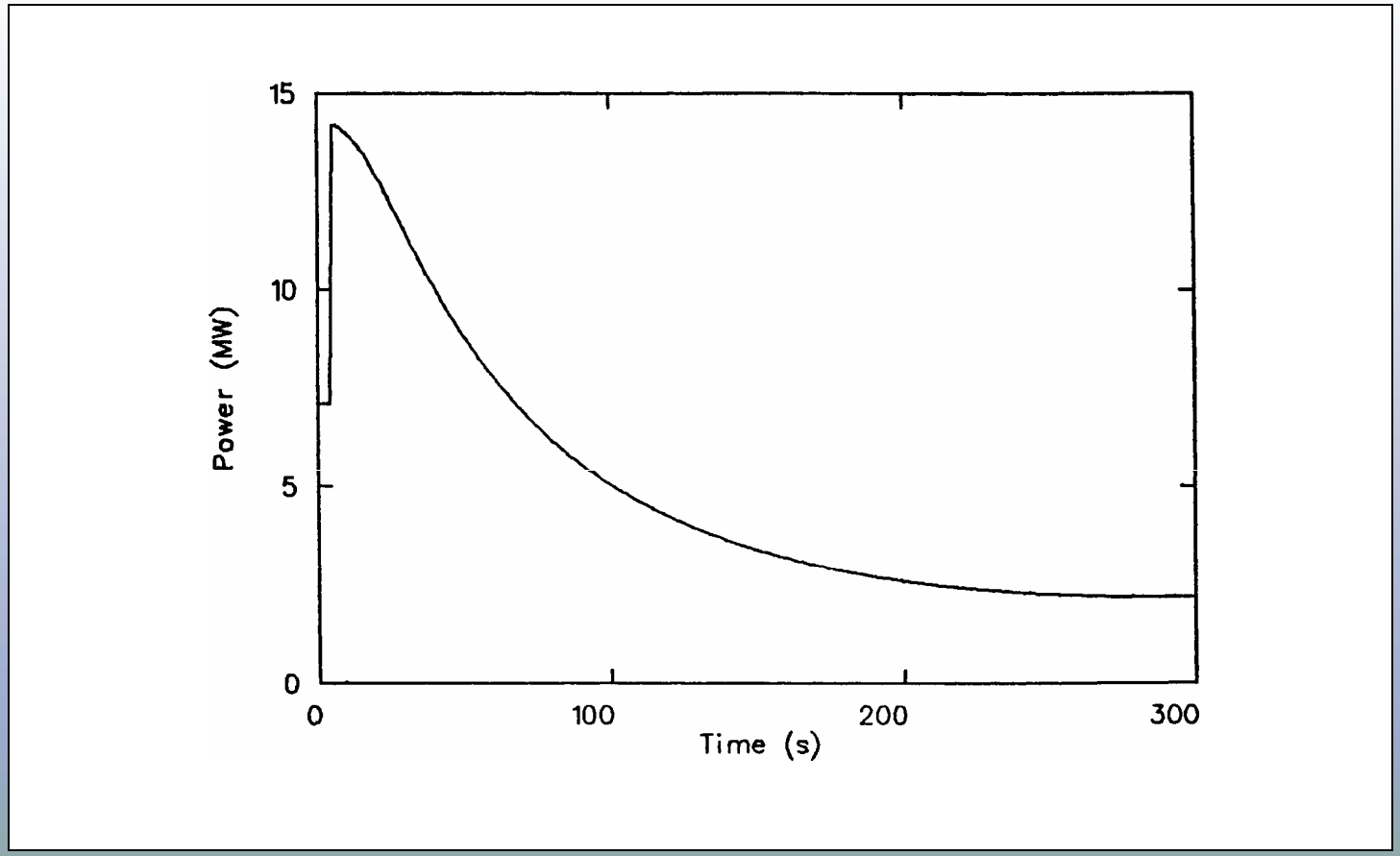
SP-100 Steady-State Conditions

Parameter	Value
Core Power (MW_t)	7.1
Mass Flow Rate per Loop (kg/s)	34.05
Loop Differential Pressure (kPa)	49.5
Loop Operating Pressure (kPa)	149.5
Hot Leg Temperature (K)	1360.9
Cold Leg Temperature (K)	1310.8
Heat Pipe Temperature (K)	837.3
Pump Radiator Power Dissipation (MW_t)	0.1191
Heat Pipe Radiator Power Dissipation (MW_t)	6.9876
Electric Power Output (kW_e)	300.0

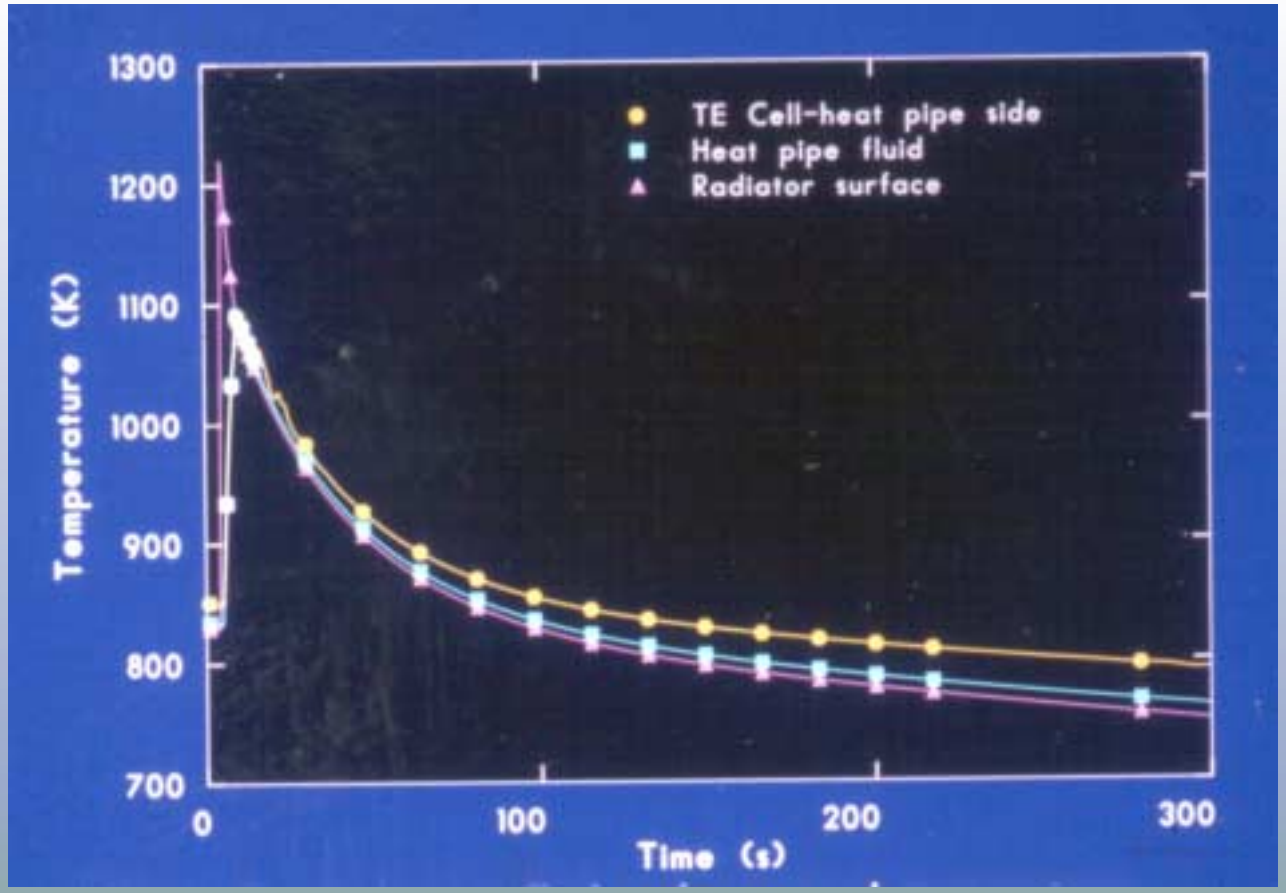
SP-100 "Demonstration Calculation"

- *Transient initiated from full power condition*
- *10 kiloton nuclear explosion occurs 10 km from the space vehicle*
- *Bomb x-rays dissipate their energy into the radiator structures*
- *Reactor power doubles from neutron flux through the core*

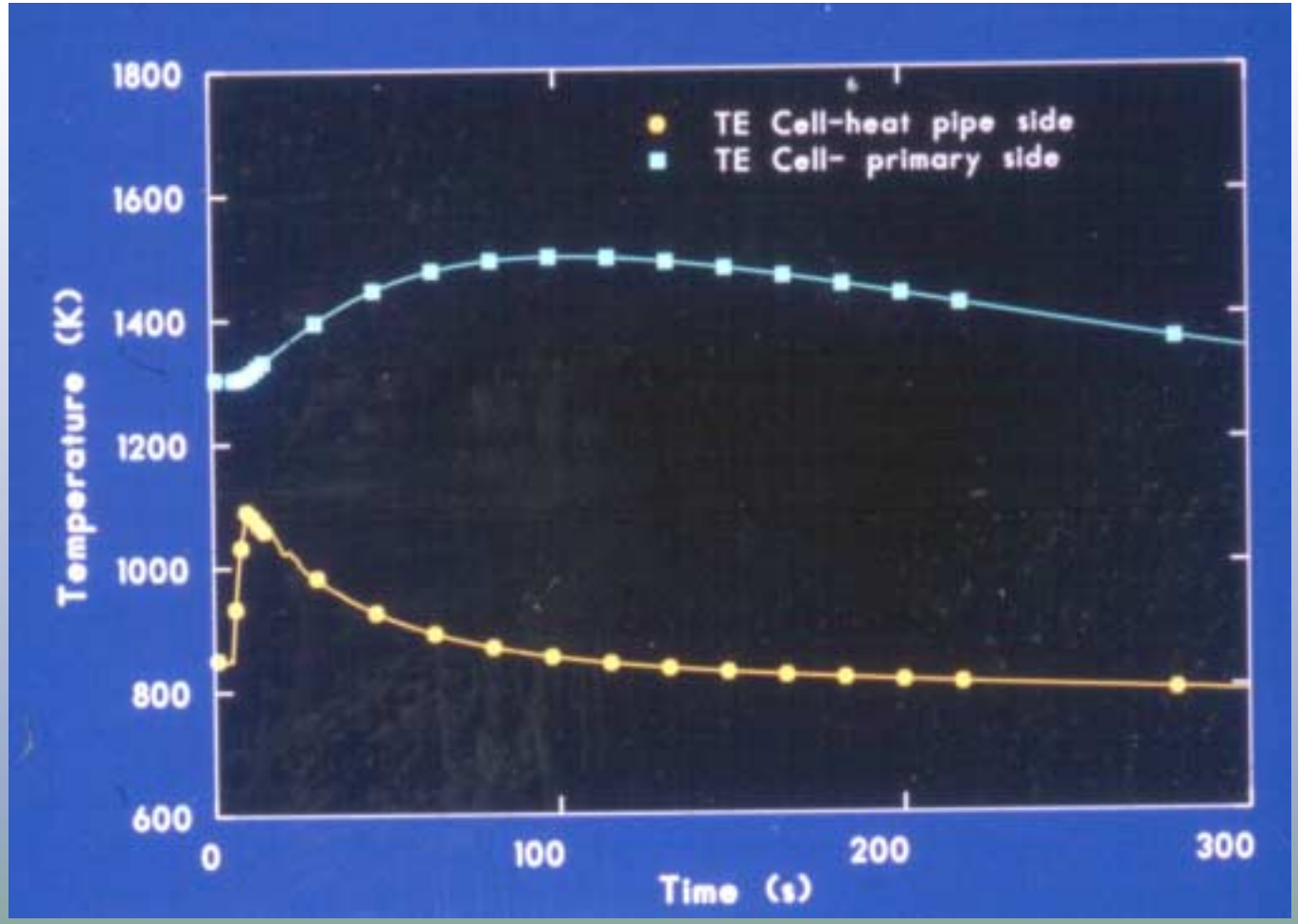
Reactor Power Response



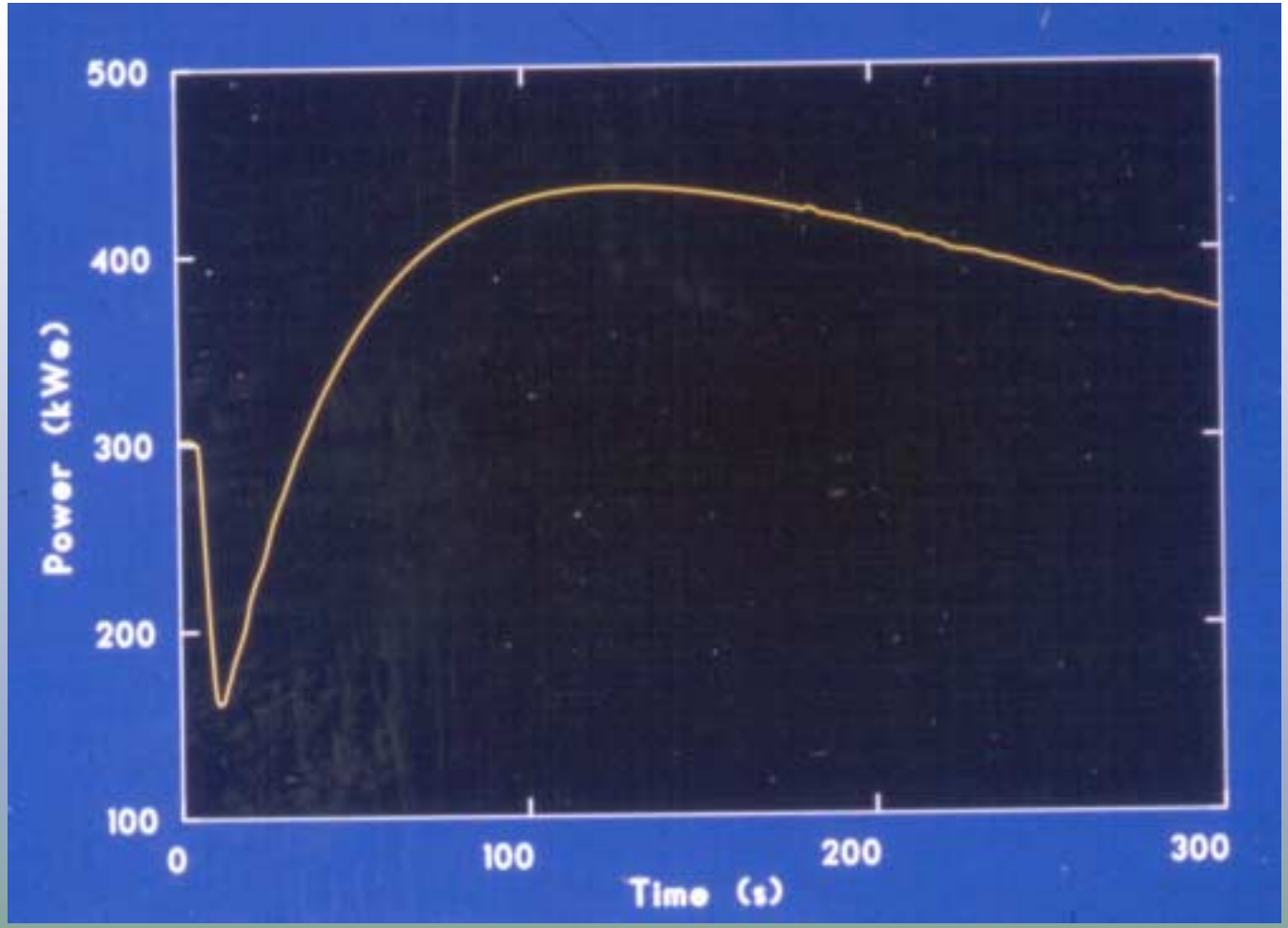
Heat Pipe Temperature Response



TEG Temperature Response



Electric Power Response



Summary

- *ATHENA contains the basic capabilities necessary to model space reactor systems*
- *New working fluids can readily be added*
- *Depending on specific design details, new or improved models may be needed:*
  - *Electromagnetic pump*
  - *Improved heat pipe model*
  - *Freeze/Thaw of liquid metal*